E & A

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1066

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. ▼ June 21, 1922

CURCULIOS THAT ATTACK THE YOUNG FRUITS AND SHOOTS OF WALNUT AND HICKORY.

By FRED E. BROOKS,

Entomologist, Fruit Insect Investigations.

IMP. BUR.

CONTENTS.

	Page.
Introduction	1
The butternut curculio	2
Distribution	2
Food plants	2
Nature and extent of injury	3
Life history	4
Natural enemies	7
The black-walnut curculio	7
Distribution	8
Food plants	8
Nature and extent of injury	8
Life history	9
Natural enemies	11
The hickory-nut curculio	11
History and distribution	12
Food plants	12
Life history	12
Natural enemies	13
The hickory-shoot curculio	14
Distribution	14
Food plants	14
Life history	14
Natural enemies	15
Methods of controlling nut-infesting curculios	16

INTRODUCTION.

Several species of snout-beetles nearly related to the common plum curculio (*Conotrachelus nenuphar* Hbst.) attack the immature fruits, tender shoots, and leaf petioles of walnut and hickory. Four such species are discussed herein, all belonging to the genus Conotrachelus and all having evidently at times been confused under the one most familiar species, *Conotrachelus juglandis* Lec. The four species throughout the several stages of their development resemble one another closely in appearance, habits, and seasonal activities, except that they select different food plants or have different methods of attack.

Several members of this group attack acorns and there are also several species of an allied group of snout-beetles (genus Balaninus) the larvæ of which feed in mature, or nearly mature, chestnuts, hickory nuts, hazelnuts, and acorns. These are not dealt with in this bulletin.

88253°—22

THE BUTTERNUT CURCULIO.[1]

The butternut curculio has been known commonly in the past either as the "walnut weevil" or "walnut curculio." It would seem that for the members of this group whose larvæ feed in immature nuts the term "curculio" is to be preferred in order to disassociate them in the popular mind from members of the Balaninus group, which have long been known as "nut weevils." The other part of the name is here restricted to "butternut" for the reason that this species appears to confine its attacks almost exclusively to our native butternut (*Juglans cinerea*) and to introduced walnuts of the butternut type. There is a very similar but distinct species to which the name "walnut curculio" could be applied with equal appropriateness. In rearing several hundred specimens the writer has failed to obtain a single individual of *C. juglandis* from infested young black walnuts (*Juglans nigra*), the species commonly attacking black walnuts being *Conotrachelus retentus* Say, described on pages 7–11. One beetle of *C. retentus* was found among a lot of beetles of *C. juglandis* reared from butternuts, and it is possible that with both species of insect there is occasional interchange of hosts.

The butternut curculio also attacks and injures seriously the fruit and small branches of various species of introduced walnuts, being especially destructive to the Japanese walnuts (*J. sieboldiana* and *J. cordiformis*) which are of the butternut type. (Pl. II, *D;* Pl. III, *B.*)

DISTRIBUTION.

The known range of the butternut curculio extends from the Provinces of Ontario and Quebec, Canada, south through the New England States, Wisconsin, Iowa, and Kansas to Alabama and Georgia. Britton and Kirk[2] record it from 20 States within the boundary just given. The distribution of the insect follows rather closely the natural range of the butternut, which is its favorite native food plant. Throughout the general range of the insect there are evidently many localities, even where host trees abound, in which it is very rarely found. In many other localities it is abundant and destructive.

FOOD PLANTS.

Britton and Kirk[2] give the food plants in the order of preference shown as follows: *Juglans cordiformis*, *J. sieboldiana*, *J. cinerea*, *J. regia*, *J. nigra*, and *J. mandshuria.* They quote Dr. Robert T. Mor-

[1] *Conotrachelus juglandis* Lec.; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

[2] BRITTON, W. E., and KIRK, H. B. LIFE HISTORY AND HABITS OF THE WALNUT WEEVIL OR CURCULIO. *In* 12th Ann. Rept. State Ent. Conn., p. 240–253. 1912.

ris, a nut grower, of New York City and Stamford, Conn., as stating that he has observed this curculio on various species of hickory. Blatchley and Leng [3] record the species as "occurring on walnut, butternut, and hickory, the larvæ breeding in the green fruit."

The present writer has found this curculio attacking extensively the fruit of our native butternut (*J. cinerea*) and the shoots and leaf petioles of the Japanese walnuts (*J. sieboldiana* and *J. cordiformis*). It was found less frequently feeding and ovipositing in the shoots of the native butternut and the fruits of the Japanese walnuts. Several beetles were found in September on the branches of a young tree of *Juglans cathayensis* growing in Arnold Arboretum, at Boston, Mass., and there were evidences of serious injury to the branches made earlier in the season by the larvæ. Similar although less extensive injury was noted on a tree of the same species growing in one of the parks of Rochester, N. Y.

NATURE AND EXTENT OF INJURY.

The injury inflicted by this insect consists of feeding punctures made by the adults in the nuts, tender tips, and leaf petioles and the burrows of the larvæ in the nuts and new growth of various species of walnuts. Extensive injury has been reported from Connecticut,[4] where young transplanted trees and trees in the nursery row have been partially or entirely killed by the larvæ working in the branches. The most serious loss of this kind has been to the Japanese walnuts, although trees of the Persian walnut have suffered to some extent. Britton and Kirk [5] describe infestation in one nursery as follows:

> In a nursery at New Canaan [Conn.], about the middle of September, Mr. Kirk noticed a row containing about 265 trees of *Juglans sieboldiana* on all of which the larvæ were tunneling in the new growth. An adjoining row of about the same number of *J. regia* trees was only slightly attacked, and another adjoining row containing about 400 trees of black walnut, *J. nigra*, were uninfested. Several hundred other trees of *J. sieboldiana* in another part of the same nursery were badly infested, not a single tree escaping. Here, also, was noticed the fall attack of the adults at the base of the leaf petioles, and two adults were collected.

During the present investigation the writer has observed serious injury to young trees of *J. sieboldiana*, *J. cordiformis*, and *J. cathayensis* in Massachusetts, Connecticut, and New York. Southward, particularly in Maryland and West Virginia, extensive attacks upon the fruit of the native butternut occur regularly. Many cases have been observed in which 50 per cent or more of the nuts dropped from trees prematurely on account of injury by the curculio larvæ, the percentage of loss being greatest in years of light crops. Farther

[3] Blatchley, W. S., and Leng, C. W. Rhynchophora or weevils of northeastern America, p. 469. 1916.

[4] Britton, W. E., and Kirk, H. B. Op. cit.

north attacks upon the fruit of the native butternut seem less extensive, although at least a few infested nuts can usually be found upon or beneath any bearing tree. A case of slight injury to the nuts was found in 1920 in Jefferson County, N. Y. At nearly the same time about 20 bearing butternut trees were examined along the St. Lawrence River, in St. Lawrence County, N. Y., and not a trace of the insect found. Beetles were reared from both shoots and fruit of *J. sieboldiana* collected at Lockport, N. Y., and larvæ were abundant in butternuts collected at Lake Winnepesaukee, in central New Hampshire.

Occasionally the larvæ are found boring in young shoots of butternut at French Creek, W. Va., oviposition evidently taking place in the tips of these shoots before the fruit is large enough to be attacked. On July 2, 1920, in the last-named locality, 60 half-grown butternuts were picked at random from the lower branches of one tree. Of these 60 nuts 48 contained egg punctures of the curculio and 12 were sound. A number of nearly full-grown larvæ were also found boring in the terminal shoots and leaf petioles. These larvæ averaged larger than those in the nuts, indicating, as in numerous other observations made, that eggs are first laid in the shoots.

LIFE HISTORY.

The butternut curculio has but one generation annually, and, like other members of the genus, passes the winter in the adult stage. In West Virginia oviposition begins in May and continues practically all summer, apparently reaching its maximum the last of June or the first of July.

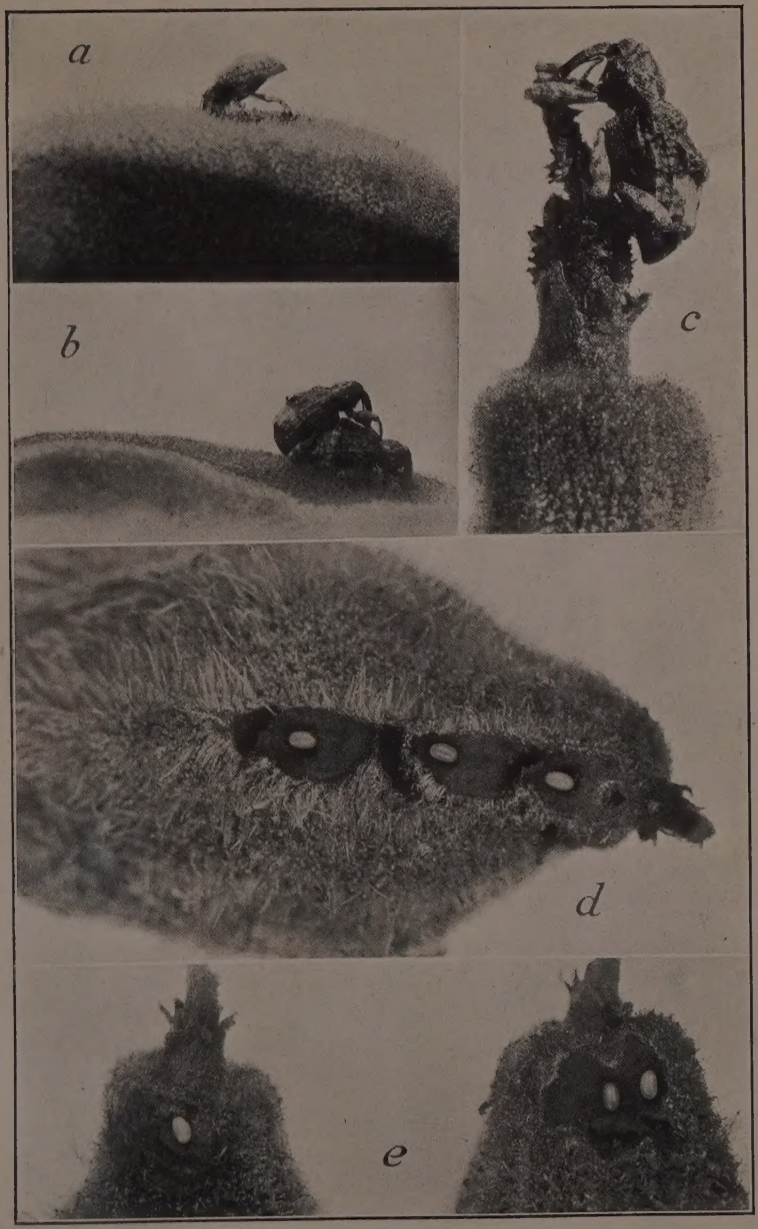
EGG.

The egg is oblong, oval, creamy white, with the surface like ground glass. (Pl. I, *D* and *E*; Pl. II, *A*, *B*, and *C*.) Three measured on July 2, 1920, were uniformly 1 mm. long by 0.6 mm. wide. Two measured on June 7, of the same year, were 0.9 mm. long by 0.6 mm. wide. Britton and Kirk[5] give the following dimensions: Length, 0.95 mm.; thickness, 0.57 mm. Most of the eggs hatch in from 8 to 10 days, although the period may extend to 15 days.

LARVA.

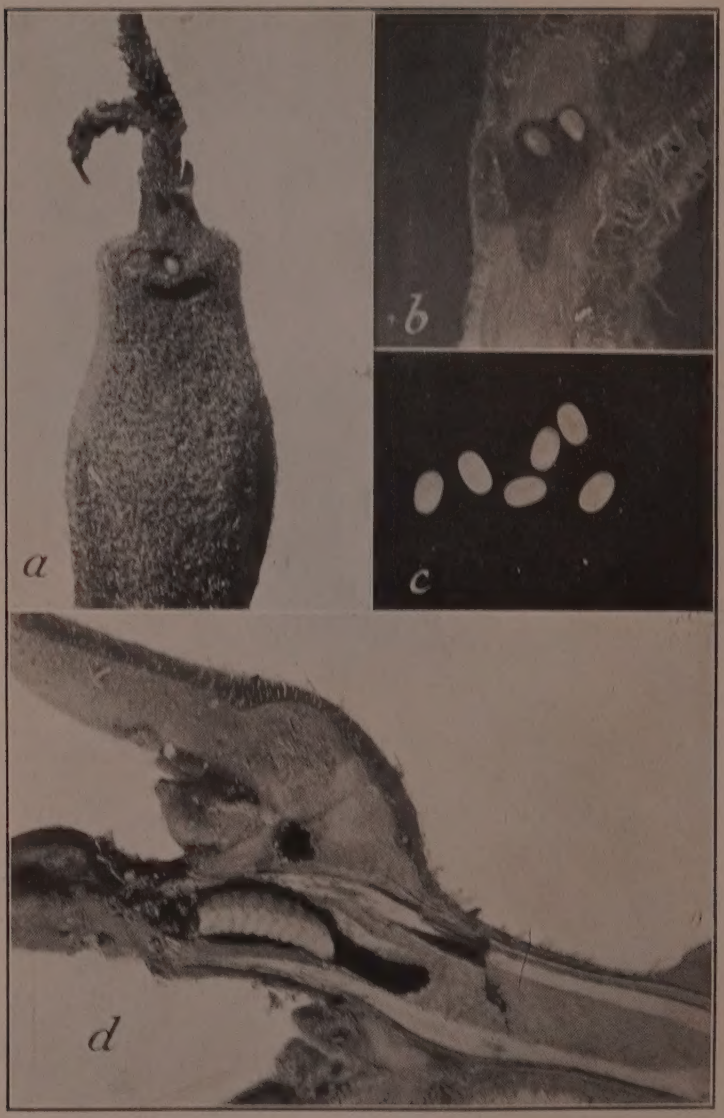
The larvæ are whitish, or dirty white, with brown head and blackish mandibles. (Pl. II, *D*; Pl. III, *A* and *B*.) The length is 12 to 13 mm. and the thickness 3 mm. Feeding in the nuts and shoots, they become full grown in four or five weeks and then enter the ground to pupate. Nuts that are attacked when very small usually furnish

[5] BRITTON, W. E., and KIRK, H. B. Op. cit.



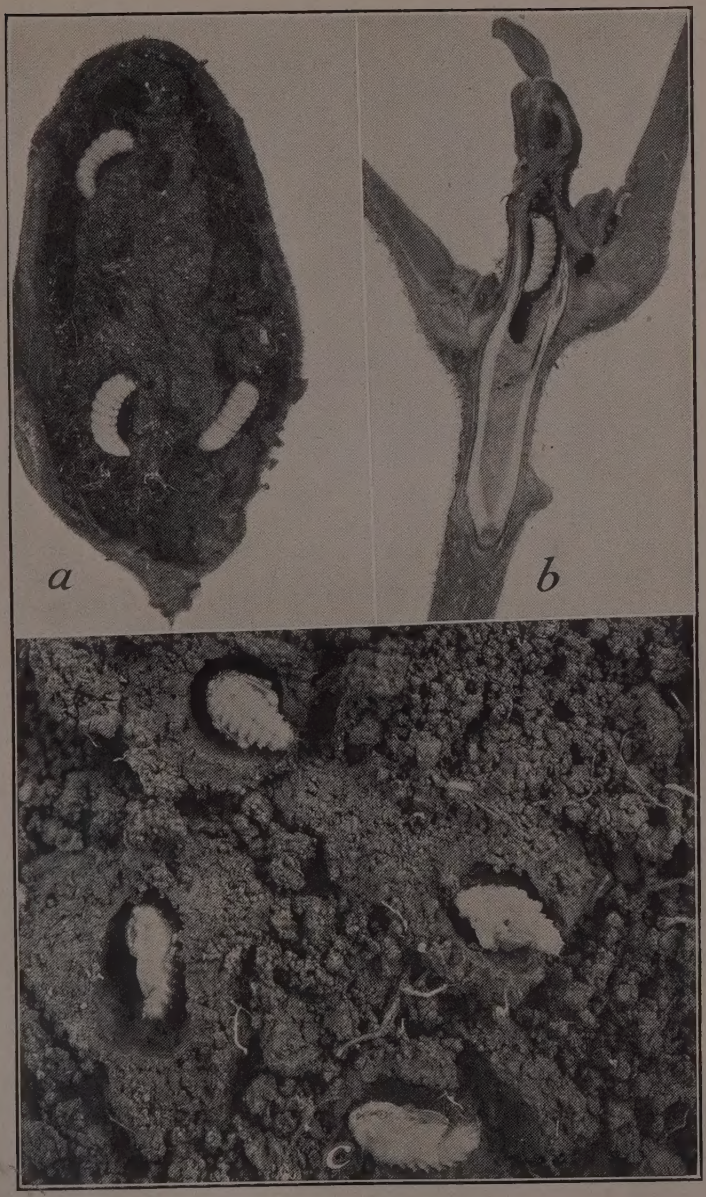
THE BUTTERNUT CURCULIO.

a, Adult curculio excavating egg chamber in butternut; *b*, adult female excavating egg chamber accompanied by male; *c*, curculio on tip of young butternut, a favorite resting place; *d*, eggs in young butternut exposed by cutting away the skin; *e*, eggs near tip of butternuts, a favorite place for oviposition while the nuts are small. All enlarged.



THE BUTTERNUT CURCULIO.

a, Egg and egg-punctures near tip of young butternut, egg exposed by removing skin of nut; *b*, eggs in shoot of Japanese walnut; *c*, eggs; *d*, larva boring in pith of Japanese walnut shoot. All enlarged.



THE BUTTERNUT CURCULIO.

a, Larvæ in husk of butternut; *b*, larva in shoot of Japanese walnut; *c*, pupæ within pupal cells in the ground. All slightly enlarged.

enough food to bring only one larva to maturity, but nuts that become infested when larger may contain from four to six larvæ which reach full growth. After leaving their feeding places preparatory to pupation the larvæ are active and crawl rapidly. When exposed to the light they have a habit of bending and catching the anal tip under the jaws and then releasing the tip with a jerk, sometimes throwing themselves in this way a distance equal to the length of the body. The larvæ issue chiefly in the early morning hours and enter the soil as quickly thereafter as possible. In West Virginia larvæ began to issue from butternuts on July 18 and continued to appear until September 4. Table 1 shows the rate of emergence.

TABLE 1.—*Time and rate of emergence of larvæ of the butternut curculio from half a bushel of butternuts at French Creek, W. Va., during the season of 1920.*

Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.
July 18	3	Aug. 5	4	Aug. 23	9
19	0	6	2	24	3
20	16	7	5	25	1
21	0	8	1	26	1
22	9	9	8	27	0
23	1	10	4	28	0
24	5	11	5	29	0
25	11	12	2	30	0
26	153	13	2	31	0
27	22	14	7	Sept. 1	0
28	10	15	4	2	3
29	2	16	0	3	0
30	1	17	0	4	4
31	0	18	4	5	0
Aug. 1	13	19	1		
2	97	20	0	Total	464
3	40	21	1		
4	1	22	9		

As set forth in Table 1, 464 larvæ issued from half a bushel of infested butternuts over a period of 49 days. It is an interesting fact that emergence was much more rapid during cool than warm weather. For example, on the mornings of July 26 and August 2, the dates of maximum emergence of the larvæ, the temperature registered, respectively, 46° and 54° F. More than half the entire number of larvæ issued on these two mornings of unusual cold.

PUPA.

The pupa (Pl. III, *C*) is creamy white, the color deepening and the eyes becoming dark as the adult stage is approached. The length averages 10 mm. and the thickness 5 mm. The entire ventral surface is sparsely covered with short, stiff hairs. The pupa occupies a smooth-walled cell from 1 to 3 inches below the surface of the ground. Nearly a month is spent beneath the ground by the insect in the prepupa, pupa, and young adult stages and then it emerges as a fully developed beetle and seeks the branches of a host tree.

ADULT.

The beetle (Pl. I, *A*, *B*, and *C*) resembles very closely the common plum curculio, being brownish gray with a variable, whitish, curved line on each side of the thorax and a broad whitish band behind the middle of the elytra. The back is marked with prominent humps and ridges and is covered with short gray and whitish pubescence. The strong curved beak is nearly half as long as the body, and the body, exclusive of the beak, averages about 7 mm. in length. The general appearance of the beetle is rough and angular.

The young beetles issue from the soil in late summer and early autumn, 64 individuals issuing in West Virginia between August 17 and September 6. Of these beetles the maximum daily emergence of 13 took place on August 27. A few beetles continued to come from earth in rearing jars up to the middle of October. These young beetles reach the trees before those of the parent generation have all died, and, like them, feed sufficiently in the autumn on the surface of terminal shoots and leaf petioles to suggest their destruction with arsenical sprays in September or early October. The beetles go into hibernation, probably in litter on the ground, with the approach of freezing weather.

The beetles issue from hibernation in the spring at about the time walnut trees come into bloom and resort at once to their host trees. They may at this time be jarred in abundance from butternut trees, a few having been taken in West Virginia by jarring black walnut and hickory trees growing near butternut trees. With very few exceptions, however, the species jarred from black walnut at this season of the year has been *C. retentus* and those from hickory *C. aratus*. This usually holds good even where the three kinds of trees grow in close proximity.

Feeding begins in a limited way soon after the beetles appear on the trees, the food consisting of stem and leaf tissues of the new growth. The feeding marks in the stems are in the form of irregular pits reaching through the bark and are sometimes extensive enough to cause the leaves and tips to droop and die. Oviposition soon begins, the first eggs being laid in the new growth which forms before the fruit is large enough to be attacked. In the native butternut most of the eggs are withheld until the nuts are large enough to receive them, this being when the nuts are about an inch long. In young and tender nuts practically all the eggs are placed in crescent-shaped marks eaten into the husk near the blossom end. (Pl. I, *E*; Pl. II, *A*.) By means of an extrusive ovipositor the egg is thrust into a small pocket excavated beneath the tongue of skin on the concave side of the crescent. The beetles are often found resting upon the remnants of the blossom that project from the tip of the young

nuts (Pl. I, *C*), and in excavating the egg chamber in such nuts the female beetle takes her position on this withered part of the blossom, and, with her head pointing toward the nut, proceeds to excavate the crescent-shaped egg chamber. On account of her method of work the concave side of the crescent faces the tip. (Pl. II, *A*.) It is not unusual to find a young butternut with a row of these crescent marks completely encircling the blossom end.

As the nuts develop and the husk becomes tougher the beetle changes somewhat her method of procedure, and instead of cutting out the crescents for her eggs, places them in simple cavities gouged into the side of the nut through small openings in the skin. Such cavities are usually arranged in groups, the skin about the wounds being marked by dark stains from slight exudations of juice and from excrement voided by the beetle during the excavating process. These groups of punctures often contain half a dozen eggs each, one having been found by the writer which contained 11.

NATURAL ENEMIES.

During this investigation two species of dipterous parasites have been reared in West Virginia from larvæ of the butternut curculio. These have been determined by Dr. J. M. Aldrich, of the United States National Museum, as *Chaetochlorops inquilina* Coq. and *Cholomyia longipes* Fab. Both species are rather abundant, the first-named, especially, rendering good service in holding the curculio in check. Other investigators have reared the following species from this host: *Metadexia basalis* G.-T., *Cholomyia inaequipes* Bigot, *Myiophasia aenea* Wied., and *Sigalphus curculionis* Fitch.

THE BLACK-WALNUT CURCULIO.[a]

In June, 1919, the ground beneath bearing black walnut trees (*Juglans nigra*) at French Creek, W. Va., was found to be strewn thickly with young nuts the size of small marbles. Examination showed that each nut contained a single dirty-white larva half an inch or less in length. A quantity of the nuts were collected and placed in rearing jars with the expectation that in due time beetles of *Conotrachelus juglandis* would be reared therefrom. When the beetles appeared, however, they were slightly different from *C. juglandis*, and specimens submitted to Mr. E. A. Schwarz, of the United States Department of Agriculture, were determined as *Conotrachelus retentus* Say, a species the habits of which had hitherto been practically unknown. Further observations proved that this species attacks commonly the young fruits of black walnut in many localities in the eastern part of this country.

[a] *Conotrachelus retentus* Say; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

DISTRIBUTION.

This species was described and named nearly a century ago by Thomas Say.[7] Since Say's description was published entomologists have from time to time collected specimens of the beetle, but no data on the feeding habits of the species have found their way into print. There are records of beetles being collected at Allegheny, Pa., Topeka, Kans., Mendenhall, Miss., and Haulover, Fla. During the present investigation the writer has collected the species at Harrisburg and York, Pa.; Hagerstown, Cumberland, and New Windsor, Md.; Morgantown and French Creek, W. Va.; Fincastle, Gala, Lick Run, Marion, McDowell, Oak Ridge, Pulaski, and Radford, Va.; and Black Mountain and Hickory, N. C.

FOOD PLANTS.

No food plants of this curculio seem to be known other than the black walnut (*Juglans nigra*) and butternut (*J. cinerea*). Of these two, the black walnut is much preferred, only one beetle of the species having been obtained in extensive rearings from butternut. Hamilton records taking the beetles by beating red oak sprouts, and the present writer has collected them from hickory trees growing close to black walnut. The occurrence of the beetles on both the red oak and hickory was probably accidental.

NATURE AND EXTENT OF INJURY.

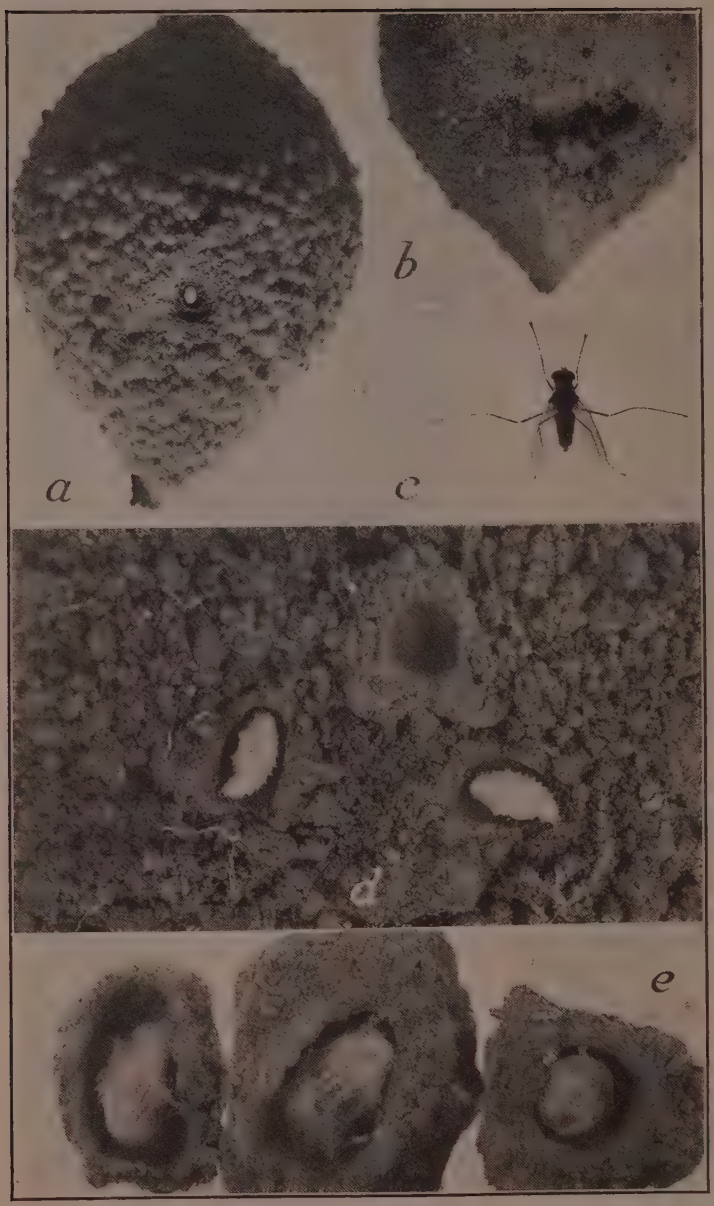
Except for its different food plant, this species corresponds very closely in all its activities as well as in appearance with the butternut curculio. The adults feed on the tender shoots and leaf petioles and make oviposition scars and feeding punctures in young black walnuts similar to those made in butternuts by the other species. The larvæ develop in young black walnuts and cause the nuts to drop, usually before they are half grown. The larvæ are occasionally, but rarely, found burrowing in the tender shoots of black walnut.

In seasons when black walnut trees are bearing a light crop of nuts a large percentage of the crop may become infested and drop, but in years of heavy fruitage the curculios do no more than to effect an unimportant thinning of the nuts. The following notes of field observations indicate degrees of infestation such as were frequently noted. On June 15, 1920, 17 newly set black walnuts were picked from the lower branches of a tree growing in a parklike woods near Cumberland, Md. Of these 17 nuts, 16 contained curculio egg punctures and the other a feeding puncture. On the 16th of the same month 50 per cent of the nuts on trees growing along the highway at New Windsor, Md., were found infested. At French

[7] SAY, THOMAS. ENTOMOLOGY OF NORTH AMERICA. (Leconte ed.) v. 1, p. 295. 1859.

THE BLACK-WALNUT CURCULIO.

a and *d*, Female beetles excavating egg chamber in young black walnuts; *b*, egg; *c*, larva constructing pupal cell in the ground; *e*, egg punctures in young walnut; *f*, pupa; *g*, egg punctures in walnuts.



THE BLACK-WALNUT CURCULIO.

a, Egg in natural position exposed by removing skin of young black walnut; *b*, group of egg punctures in half-grown black walnut; *c*, parasitic fly *Cholomyia longipes*; *d*, pupæ within pupal cells in earth; *e*, cocoons of the parasite *Thersilochus conotracheli* occupying the pupal cells of the curculio after killing and devouring the host larvæ. All enlarged.

Creek, W. Va., 400 young nuts were gathered at random from the lower branches of four black walnut trees growing in a pasture field. Of this lot of nuts 289 contained 466 egg punctures and the remaining 111 were sound. In another instance in the locality last mentioned 1,447 infested nuts dropped from one tree during the season.

So far as observations have been made, the black walnut curculio seems much more abundant and injurious in the latitude of Maryland and West Virginia than within the range of the black walnut farther to the north. In the vicinities of Trenton, N. J., Lancaster, Pa., Rochester and Lockport, N. Y., and Wallingford, Conn., a number of bearing black walnut trees were examined without finding any evidences of the presence of the curculio. Locality records by various entomologists and observations made during the present investigation indicate a southern rather than a northern range for this species.

LIFE HISTORY.

EGG.

The egg (Pl. IV, *B;* Pl. V, *A*) is oval, oblong, creamy white, surface delicately granulose, 1 mm. long by 0.7 mm. wide. Eggs that are deposited in young, tender nuts are placed beneath the flap of skin within a crescent-shaped puncture eaten out of the side of the nut (Pl. IV, *E*, *G*). In the more solid husk of half-grown nuts the eggs are inserted in less elaborate punctures which resemble pin pricks and extend directly into the husk. (Pl. V, *B*.) These simple egg punctures in the more nearly mature nuts are usually formed in groups of from three to six on the side of the nut.

About a dozen eggs deposited in nuts on the trees on July 15 hatched on the morning of July 22 and an equal number deposited on July 16 hatched on July 23, an incubation period in both cases of 7 days under natural conditions. Two other lots of eggs laid and kept in an open insectary hatched in five and six days, respectively. In West Virginia oviposition begins normally during the last days of May and continues through June and most of July.

LARVA.

The larva (Pl. IV, *C*) is creamy white with brown head, legless, and fusiform. It assumes naturally a curved position and is sparsely clothed with short, stiff hairs. The length is 11 mm. and the thickness 3 mm. As soon as hatched it begins to feed from the side of the oviposition wound, and, in young nuts, soon devours the whole interior. In the older nuts feeding is done chiefly in the husk. The infested nut adheres to the branch until the larva is at least half grown, and then drops, the larva continuing to feed while the nut

dries and hardens on the ground. When the larva is full grown it ceases feeding, assumes a clearer cream color, and, after a period of a week or two of inactivity within the nut, cuts its way out through the shell and enters the ground to a depth of from 2 to 4 inches to pupate. Larvæ may be found in the nuts from early in June until late in September. In one lot of 805 larvæ which issued from infested black walnuts kept in rearing jars the first larva left the nut on July 14 and the last on September 21. These larvæ, like those of the butternut curculio, chiefly issued early in the morning and the largest numbers always in cool weather. In small green nuts only one larva matures to the nut, but two or three larvæ may develop together in a large nut. Apparently where several larvæ hatch and begin feeding in a small nut one individual always kills and devours the others. In two or three instances one larva was found killing and eating its fellow. On entering the ground the larva seeks a place where the soil is solid and fashions a smooth-walled cell (Pl. IV, *C;* Pl. V, *D*), where it rests for several days before pupating.

PUPA.

The pupa (Pl. IV, *F;* Pl. V, *D*) is white and is about 9 mm. long by 3 mm. thick. The abdomen, thorax, and wing pads are covered thinly with short, stiff hairs, these hairs being shortest on the wing pads. The pupa occupies an unlined earthen cell from 2 to 4 inches beneath the surface of the ground. The pupa stage covers a period of from two to three weeks.

ADULT.

The mature beetle (Pl. IV, *A* and *B*) is dull reddish-brown and covered with grayish pubescence. There is a lighter colored, indistinct, broad band behind the middle of the elytra and a vague, broken line of the same lighter shade on each side of the thorax. The snout is half as long as the body and the back is ridged and punctured. The length averages from 6 to 7 mm. This beetle in size and general shape resembles very closely the butternut curculio but its color markings and elytral sculpturing are less pronounced.

The newly developed beetles begin issuing from the ground in August; the first specimens were obtained in this investigation on August 7. In one rearing cage 75 beetles came from the ground between August 13 and September 2, the maximum emergence taking place from August 24 to 29.

In late summer and early autumn the young beetles may be found on their host trees, where they apparently feed on the leaf petioles before seeking their hibernation quarters. The beetles live through the winter, probably hidden in the duff at the surface of the ground,

and resume activity in the spring in time to be on black walnut trees when the male catkins of the walnut are fully developed. As soon as the leaves and tender shoots appear the beetles attack them, sometimes feeding rather extensively. Soon thereafter they begin egg-laying in the young fruit. There is considerable variation in the time the fruit sets on individual trees of the black walnut in any locality and the beetles collect on the trees where the developing nutlets are at the stage just to their liking. This is immediately after the female catkins on the point of the nut are beginning to wither. Most of the eggs are deposited in nuts at this stage of their development, although the beetles continue to oviposit to some extent in nuts that are larger.

The beetles live normally throughout most of the summer and oviposit over a period of at least two months. Several overwintering beetles confined in screen cages placed over walnut branches on the trees lived until the last of August. It is thus possible in late summer to find the parent beetles and their mature offispring together on the trees.

NATURAL ENEMIES.

At least five species of insect parasites were found attacking the black walnut curculio in its larva and pupa stages. Three species of parasitic flies, determined by Dr. J. M. Aldrich as *Chaetochlorops inquilina* Coq., *Cholomyia longipes* Fab. (Pl. V, *C*), and *Fannia canicularis* L., were reared from this host in considerable numbers. Two hymenopterous parasites, determined by Mr. R. A. Cushman as *Triaspis curculionis* var. *rufus* (Riley) and *Thersilochus conotracheli* (Riley) (Pl. V, *E*) were also obtained in the rearing jars. Still another parasite, determined by Mr. R. A. Fouts as a new species of Belyta, was found in jars in which this curculio was being reared.

THE HICKORY-NUT CURCULIO.[8]

The hickory-nut curculio is very similar to the two species just discussed, but it attacks the immature nuts of various kinds of hickory instead of walnuts. The beetles appear upon the trees somewhat later in spring than the other two and lay their first eggs in hickory nuts that are at least half grown, although before the nut kernels have begun to form. The most conspicuous manifestation of the presence of the insect is the dropping of the infested nuts about midsummer. It is not unusual in July and August to find in some localities the ground beneath bearing hickory trees strewn thickly with green nuts. Examination of these nuts will disclose a brownish oviposition scar

[8] *Conotrachelus affinis* Boh.; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

on the side of the nut (Pl. VI, *C*) and a whitish larva feeding within. (Pl. VI, *D*.) The dropping of nuts from this cause is sometimes very heavy.

HISTORY AND DISTRIBUTION.

This species was described and named in 1837 by Boheman.[9] Since the original description was published the species has been referred to occasionally by entomologists, but it has at no time attracted extensive notice. It has been recorded from the States of New Jersey, Ohio, Virginia, West Virginia, Louisiana, Florida, and the District of Columbia.

FOOD PLANTS.

During the last 15 years the writer has reared this curculio frequently from hickory nuts in West Virginia. Pierce[10] has reared it from hickory nuts in Louisiana. Apparently its attacks are confined to the nuts of various species of hickory. In West Virginia the nuts of the pignut hickory, *Hicoria glabra*, seem to be preferred to those of other species, although shagbark hickory nuts, *H. ovata*, are sometimes attacked extensively. Nuts of *H. alba* and *H. minima* are attacked to some extent and it is probable that injury may occur to the nuts of all species of hickory that grow within the range of the insect.

LIFE HISTORY.

EGG.

The egg (Pl. VI, *B*) is oblong, elliptical, translucent white, the surface smooth and shiny. The average dimensions are 1 mm. long by 0.6 mm. thick. The eggs hatch in from five to seven days.

LARVA.

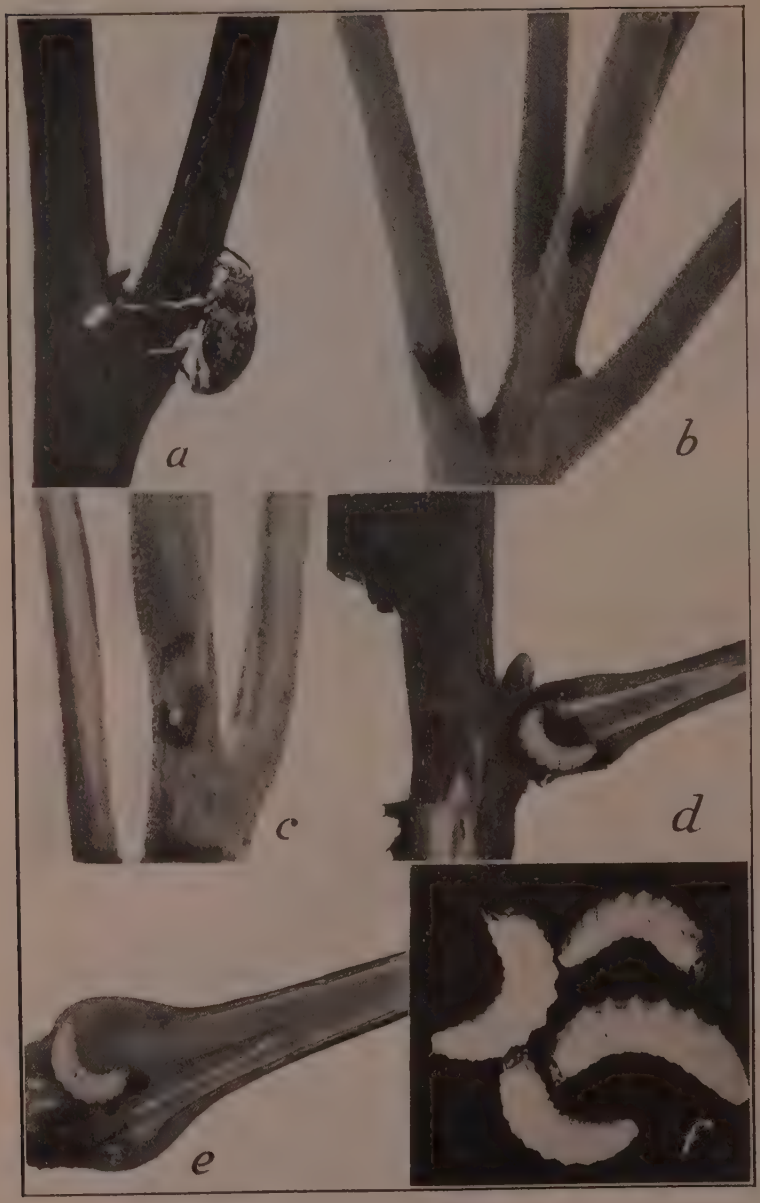
The larva (Pl. VI, *D*) is white with light brown head, full-grown specimens measuring 12 mm. in length. The larvæ are practically identical with those of the preceding species except that they taper somewhat more abruptly at the anal end than *Conotrachelus retentus*, and the bristles, with which the body is sparsely clothed, are shorter and less conspicuous than in *C. juglandis*. They are found feeding singly in fallen nuts during the months of July and August. The infested nuts drop about 20 days after oviposition takes place, or about 2 weeks after the larvæ begin to feed. At the time of dropping, the nuts average from one-half to two-thirds grown.

[9] Boheman, C. H., *In* Schoenherr, C. J. Synonymia insectorum. Genera et species curculionidum, t. 4, pars. 1, p. 429–430. 1837.

[10] Pierce, W. Dwight. On the biologies of the rhynchophora of north america. Studies from the Zoological Laboratory of the University of Nebraska, No. 78. Nebr. State Bd. Agr., Rpt. Zoologist, p. 274. 1907.

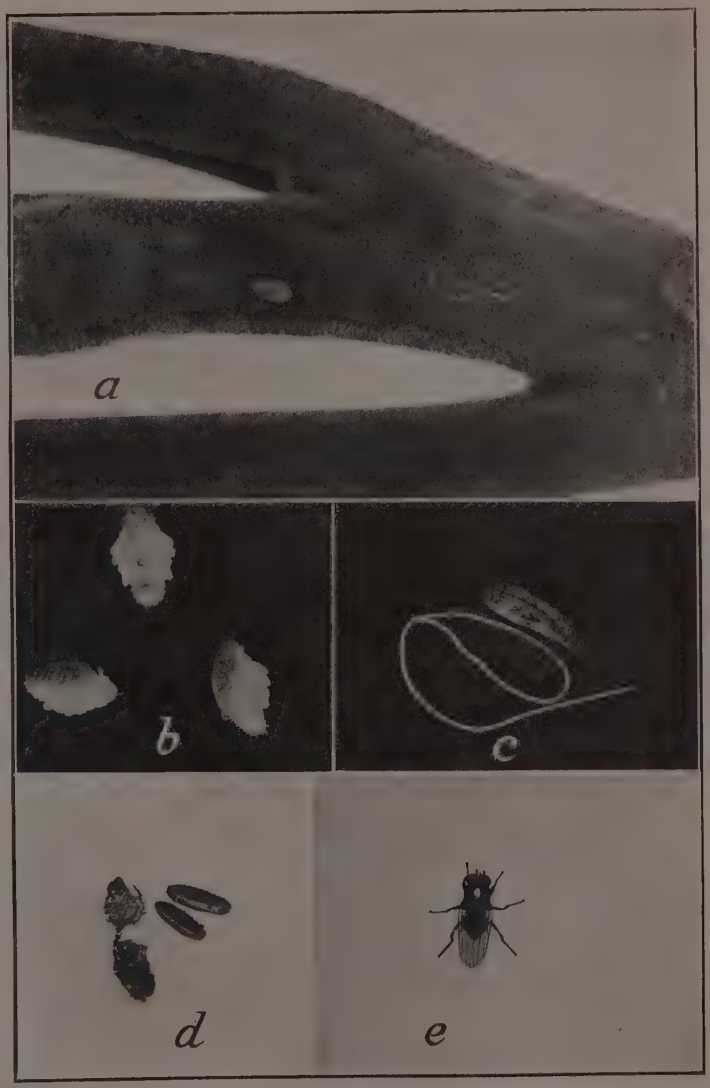
THE HICKORY-NUT CURCULIO.

a, Adult curculio resting on hickory nut; *b*, egg exposed by cutting away the husk of the nut from around the egg chamber; *c*, oviposition scars in shagbark hickory nuts; *d*, larva feeding in shagbark hickory nut; *e*, parasitic fly *Cholomyia longipes*.



THE HICKORY-SHOOT CURCULIO.

a, Adult excavating egg chamber in leaf petiole; *b*, oviposition scars; *c*, egg exposed by cutting away bark; *d* and *e*, larvæ feeding at base of leaf petioles; *f*, larvæ



THE HICKORY-SHOOT CURCULIO.

a, Egg in hickory shoot, exposed by removing bark; *b*, pupæ; *c*, hairworm parasite of larva by dead body of its host; *d*, curculio larva killed by larvæ of parasitic fly, *Chactochlorops inquilina*, with pupæ of parasite on right; *e*, adult parasite *C. inquilina*.

found parasitic upon the larvæ; one of these was determined by Mr. R. A. Cushman as *Triaspis curculionis* var. *rufus* (Riley) and the other by Mr. C. F. W. Muesebeck as a new species of Microgaster. Pierce[11] records rearing the parasitic fly *Myiophasia aenea* Wied. from this host.

THE HICKORY-SHOOT CURCULIO.[12]

Soon after the growth of hickory begins in the spring the tender tips and leaf petioles may be found disfigured by dark, V-shaped marks on the bark about an eighth of an inch long. (Pl. VII, *B*.) These are the egg punctures of a small snout-beetle which may be known as the hickory-shoot curculio. Often these marks occur in series of from 5 to 10 along the shoot, one above each leaf axil. Examination of these marks usually discloses either the single white egg (Pl. VII, *C;* Pl. VIII, *A*) or a small white grub feeding in the stem (Pl. VII, *D* and *E*). The affected tip or leaf usually withers and drops as a result of the injury. No instance of serious loss from this insect has come under the writer's notice, but injurious attacks, especially to newly transplanted hickory trees, are a possibility.

DISTRIBUTION.

This species was described from Kentucky in 1824 and has since been recorded from Massachusetts, Connecticut, New Jersey, Florida, and Texas. The writer has found it abundantly at French Creek, W. Va., and has observed its work in other West Virginia localities.

FOOD PLANTS.

This curculio has been observed attacking the shoots of the following hickories in West Virginia: *Hicoria minima*, *H. ovata*, *H. alba*, *H. glabra*, and *H. pecan*.

LIFE HISTORY.

EGG.

The egg (Pl. VII, *C*; Pl. VIII, *A*) is oval, oblong, creamy white, semitransparent, and averages 1.1 mm. by 0.7 mm. It occupies a shallow cavity at the side of an elongate slit which the female beetle makes with her snout in the bark of tender twigs and leaf petioles. (Pl. VII, *A*.) After the egg is deposited the bark over the egg cavity and along the edges of the slit turns dark and the wound shows as a blackish, triangular spot on the green bark. (Pl. VII, *B*.) Several eggs laid on May 24 hatched on May 30, the incubation period being six days.

---

[11] PIERCE, W. DWIGHT. A LIST OF PARASITES KNOWN TO ATTACK AMERICAN RHYNCHOPHORA. *In* Jour. Econ. Ent., v. 1, no. 6, p. 390. 1908.

[12] *Conotrachelus aratus* Germ., suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

LARVA.

The larva (Pl. VII, *D*, *E*, and *F*) is yellowish white with brown head and black jaws and is covered with scattering, short bristles, those on the dorsal surface of the last three segments being longer than those elsewhere. The length of the larva averages 10 mm. and the thickness at the middle 2 mm. Except for its slightly smaller size it is practically indistinguishable from those of other species described herein.

The favorite feeding place of the larva is in the heart of the bulb-like swelling at the base of the leaf petiole. (Pl. VII, *D* and *E*.) It also mines in the pith of the shoots and leaf stems, making burrows an inch or two long. The season of activity is in the spring and early summer when the new growth is tender.

PUPA.

The delicate, white pupa (Pl. VIII, *B*) is characteristic of the group and occupies an earthen cell from one-half inch to 2 inches below the surface of the ground. The pupa stage covers a period of not more than two or three weeks.

ADULT.

The beetle (Pl. VII, *A*) is considerably smaller than any other of the curculios discussed herein, an average specimen measuring 5 mm. in length and 2 mm. in thickness. The color is dull grayish brown with a more or less indistinct, broad band of yellowish pubescence behind the middle of the elytra and a narrow line of the same color on each side of the thorax. The snout is stout and curved and as long as the head and thorax combined.

The newly transformed beetles issue from the ground in midsummer and probably spend thereafter a period of comparative inactivity on hickory trees before hibernating in the autumn. With the bursting of hickory buds the following spring they reappear and begin ovipositing as soon as the shoots are a few inches long. They feed rather freely at this time, eating out small pits which extend through the bark of the young growth. Beetles were found frequently hiding between the folds of the expanding buds of hickory. In ovipositing the female spends 30 to 40 minutes in preparing a place for the egg, and while thus engaged is often guarded closely by a male.

NATURAL ENEMIES.

The larvæ while feeding and developing became rather heavily parasitized, at least 50 per cent of them dying from this cause during the two seasons they were kept under observation. Three species of

flies, determined by Dr. J. M. Aldrich as *Myiophasia globosa* Towns., *Cholomyiæ longipes* Fab., and *Chaetochlorops inquilina* Coq. (Pl. VIII, *D* and *E*), were reared from the larvæ. Two larvæ in rearing cages died when full-grown and from each of their bodies there issued a hairworm several inches long, the species of which was not determined (Pl. VIII, *C*).

METHODS OF CONTROLLING NUT-INFESTING CURCULIOS.

The dropping of curculio-infested walnuts and hickory nuts before the larvæ within them mature affords an opportunity for destroying the young insects by collecting and burning, or otherwise disposing of the fallen nuts. This method can be resorted to with success, however, only in cases of isolated trees or plantations. In localities where the nut trees abound in woods a sufficient number of the curculio beetles will develop on them to visit and injure any near-by plantations of the same kind. Where this means of reducing the insects is practiced collections should be made as often as once a week in order to secure the nuts before the larvæ leave them to enter the ground for the completion of their development.

All the curculios discussed herein do more or less feeding in the beetle stage before oviposition begins in the spring. A considerable part of this food consists of the surface tissues of stems, leaves, and fruit. This makes it possible theoretically to destroy the beetles before their eggs are laid by spraying with arsenical poisons. Limited experiments by the writer indicate that lead arsenate applications soon after growth starts in the spring can be counted on to give good results in reducing injury, at least from the butternut and black walnut curculios.

Britton and Kirk[13] have found that spraying walnut trees with lead arsenate at a strength of 6 pounds to 50 gallons of water is an effective method of controlling the butternut curculio. Morris,[14] in writing of attacks of the butternut curculio which were so extensive as to kill nearly 300 young English walnuts and several hundred young Japanese walnuts, states that subsequent spraying with 1 pound of lead arsenate to 10 gallons of water killed the beetles and prevented further injury.

---

[13] Britton, W. E., and Kirk, H. B. Op cit.

[14] Morris, Robert T. Method for combating the walnut weevil. *In* Amer. Nut Journ., v. 10, no. 5, p. 71. 1919.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1076

Washington, D. C. PROFESSIONAL PAPER July, 1922

BIOLOGY OF THE LOTUS BORER (PYRAUSTA PENITALIS Grote).

By GEORGE G. AINSLIE, *Entomological Assistant*, and W. B. CARTWRIGHT, *Scientific Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology.*

CONTENTS.

	Page.		Page.
Introductory	1	Pupation of the second generation	7
Systematic history	2	Habits of the moths	8
Studies at Knoxville, Tenn.	2	The egg	9
Life cycle	4	Food plants	10
Feeding habits on the leaves	5	Enemies	10
Feeding habits on the pods	6	Literature cited	13
Pupation of the first generation	7		

INTRODUCTORY.

In American literature two distinct species have been confused under the name *Pyrausta penitalis* Grote. One of them, the smartweed borer, has recently been described as new under the name *P. ainsliei* by Carl Heinrich (*16*[1]), of the Bureau of Entomology. The other, the lotus borer, described originally by Grote (*1*) and later redescribed by Smith (*3*) as *Botis nelumbialis*, has been casually studied by several observers, but up to the present time no complete account of its biology has been available. The two species are closely related and very similar, in many morphological and biological characters, to the recently introduced European corn borer, *P. nubilalis* Hübner. It seemed possible that a close study of the life history and habits of the two native species might bring to light some facts which would help in determining the potentialities of the new pest. In accordance with this plan the first paper dealing with *P. ainsliei* from the biological side has already been published (*18*). The present paper deals with the similar aspects of *P. penitalis*. Both the results

[1] Reference is made by number (italic) to "Literature cited," p. 13.

of the writers' observations and previously published data are included herein. The morphology and diagnostic characters of this and the other species mentioned, which have already been admirably worked out by Heinrich (*16*) and also by Flint and Malloch (*17*) and Mosher (*13*, *15*), are largely omitted from this discussion.

SYSTEMATIC HISTORY.

Pyrausta penitalis was first described by Grote (*1*) under the generic name Botis from material taken on *Nelumbo lutea* at Lawrence, Kans. In 1890 it was redescribed by Smith (*3*) as *Botis nelumbialis* from "Egyptian" (more properly "Indian") lotus, *N. nucifera*, at Bordentown, N. J. Thinking that he was dealing with this species, Coquillett (*2*) published some notes on a form which has since been shown (*12*, *14*) to be distinct, probably *P. futilalis*. Riley and Howard (*4*, *p. 349*, Townsend (*5*, *p. 467*), Coquillett (*7*, *pp. 15*, *17*, *19*, *27*), and Viereck (*11*, *p. 453*) record parasites which will be more fully noted later. Hart (*6*, *p. 180*), gives some scattered biological information and descriptions of the various stages as observed on *N. lutea* along the Illinois River. Coquillett (*7*) first used the name in its present form, and Dyar (*9*, *p. 391*) lists the species as occurring in the south Atlantic States, with *B. nelumbialis* Smith as a synonym. Chittenden (*12*) summarized all the facts available up to the time of his paper and from them formulated a tentative life cycle which, because of the fact that he was considering two species, one of them at the time undescribed, will have to be considerably modified. Welch (*14*) has made the latest contribution to our knowledge of the species, and his observations, made at Sandusky Bay, Lake Erie, although good, are incomplete as to life history, because they covered only a small part of the growing season. His conclusions, however, come nearer the facts than any hitherto published.

STUDIES AT KNOXVILLE, TENN.

FIELD COLLECTIONS.

The authors' work on the species dates from July 19, 1919, when, after considerable search, a plantation of the yellow lotus or water chinquapin (*Nelumbo lutea*) (Pl. I) was located at Kimberlin Heights, about 15 miles from our laboratory at Knoxville, Tenn. This plantation consisted of a dense border of the plants surrounding a mud-bottomed pond of about 3 acres on the campus of a small denominational school. It was said that the plants had started several years before from seeds thrown into the pond by one of the students. As nearly as the authors have been able to ascertain, this is now the only occurrence of the plant in eastern Tennessee, although it is known

that before the coming of the white man the Indians cultivated it for its edible seeds and rootstocks in many places along the Cumberland and Tennessee Rivers.

The first examination showed that the plants were heavily infested by the very insect the writers desired to study. Throughout the rest of the season of 1919 frequent careful studies were made of the conditions at Kimberlin Heights, and quantities of material were brought to the laboratory for closer study and for rearing purposes.

At the time of the first visit, July 19, the main blooming season was closing. There were still a few flowers and scattering buds. None of the seed pods had ripened, but the oldest ones were fully grown. A count showed that there were 472 pods in all stages in the plantation. Of these, 80 (17 per cent) showed work of the larvæ and were collected and examined individually. They contained 39 empty pupal shells, 23 pupæ, and 2 larvæ in the prepupal stage. Moths began to emerge at once, or, more properly, continued to emerge from the pupæ until July 28, when the last one appeared.

On July 19, larvæ, evidently the progeny of the earliest moths, were found feeding on the leaves. These larvæ were mostly small, only a few half grown, and none mature. When taken to the laboratory for rearing they began to pupate July 28, and the first moths of this generation emerged August 4. From this time on there was a continual overlapping of generations, larvæ both from the later moths of the first generation and from those of the second being inseparably mixed. From these larvæ and from others collected on July 28, moths continued to emerge until August 27. On August 5 no very small larvæ could be found. The youngest observed probably were in the third instar, but several egg masses were found, so it seemed probable that the last moths of the first generation had not yet disappeared. On this same date it was also found that the larvæ of this generation instead of seeking pupation quarters in the seed heads were burrowing in the upper ends of the petioles of the older leaves, preparing there a pupation chamber, and that a few had already pupated. One empty pupa shell was found in this location, which seemingly indicated that the second generation of moths had just begun to emerge. More pupæ and prepupal larvæ subsequently were found in the petioles, and larvæ, in gradually lessening numbers, still feeding on the leaves and in the petioles, were found until September 18. Three were found on this date, but thereafter the most thorough search of the lotus and of all likely hiding places in the vicinity of the pond failed to reveal a trace of their whereabouts.

A further and more careful study in this locality was planned for 1920, but for some obscure reason the lotus was very much less vigorous. Comparatively few leaves and buds appeared and only a few small larvæ were found in colonies on June 29.

REARING RECORDS.

So much for field observations. On each examination of the pond material was collected and brought to the laboratory for rearing. The results obtained throw additional light on the seasonal habits of the moths. As stated above, pupæ taken in the seed heads July 19 continued to develop moths until July 28. Larvæ taken at the same time on the leaves varied greatly in size, some of them being very small. The first of these pupated July 28, the last August 15. Moths emerged from August 4 to August 22. Another collection of larvæ made from the leaves July 28 pupated August 3 to August 18, and moths emerged August 12 to August 27. A mass of eggs found August 6 hatched August 9, and the larvæ were reared. They pupated August 28 to September 2, and the moths emerged September 9 to September 17. Another series of larvæ taken both from petioles and leaf blades on August 5 pupated from August 6 to August 22, and moths emerged August 13 to August 29. Larvæ from a lot of 67 collected August 15 pupated from August 17 to September 12, and moths emerged August 28 to September 22.

LIFE CYCLE.

Assuming for the present, as seems probable, that the species passes the winter in the larval stage, it is evident that the life history must be substantially as follows:

The overwintering larvæ pupate and the moths emerge and oviposit about mid-June. The resulting larvæ feed on the leaves, and when fairly grown, about July 1, seek the flowers and enter the young pods, feeding upon them to some extent and pupating within them. The moths of this first generation emerge from July 7 to July 28. Eggs are at once produced by these moths and constitute the first stage of the second generation. The eggs soon hatch, and the oldest of the larvæ produced are approximately half grown by July 19; but moths of the first generation continue to oviposit until about August 5, so that second-generation larvæ are hatching continuously from July 10 to August 8. A collection of these larvæ made July 28 pupated August 3 to 18 and moths emerged August 12 to 27. These larvæ of the second generation feed on the leaves and pupate in the upper ends of the leaf petioles.

The moths of the second generation give rise to the third-generation eggs and larvæ, which survive the winter and constitute the spring generation. It seems possible that some of the smaller larvæ of the second generation seek hibernation quarters instead of completing their growth the same fall. In this case there would be only two generations annually, but it seems probable that there are three generations as a rule. Their behavior from the time the larvæ seek

PYRAUSTA PENITALIS.

A, Partial view of pond at Kimberlin Heights, Tenn., showing *Nelumbo lutea* flowers, ripe pods, and margin of old dying leaves floating on water. *B*, Method of pod development in lotus: *a*, Bud; *b*, growing pods in horizontal position; *c*, erect, mature pods; *d*, pod deformed by work of borer.

PYRAUSTA PENITALIS.

A, Portion of plantation at Kimberlin Heights, Tenn., showing close association of lotus and cat-tail rush. *B*, Upper end of leaf petiole, opened to show pupal cavity and cocoon. *C*, Same as in *B*. Leaf cut in half and petiole split to show position of pupal cavity.

winter quarters in the fall until the young larvæ of the first generation appear on the leaves in June is unknown, and the outline here given for that period is hypothetical.

FEEDING HABITS ON THE LEAVES

After hatching, the larvæ feed gregariously for a time, gnawing off the epidermis of the leaf in irregular patches, first protecting themselves with a shielding network of brownish silk stretched across some slight concavity of the leaf or producing such a concavity by its tension. They soon scatter, each forming a similar retreat of its own (Pl. II, F), either in the center of the leaf above the petiole attachment or around the margin where the edge is easily drawn up a little to form the necessary free space beneath the web (Pl. III, A, B). Less often a larva locates on the blade between the center and the margin. Protected and partially screened by the webs, the larvæ strip the epidermis from the leaf, those at the center in a more or less radiate pattern and those at the margin following the periphery. They extend their retreat as they exhaust the food supply and occasionally prolong the feeding area irregularly inward toward the disk of the leaf. At no stage is the entire substance of the leaf eaten. The areas from which the epidermis is stripped soon turn brown, dry, and fall out, leaving the leaf lacelike along the margin (Pl. III, D) and generally tattered in appearance.

Although at Kimberlin Heights no larvæ were observed in the act, it is evident that they moved about from leaf to leaf and from one portion of a leaf to another. Small feeding webs were often found uninhabited, and tiny larvæ were found in retreats evidently occupied previously by much larger ones. Where several larvæ occurred on one leaf the retreats often overlapped around the margin, giving the effect of a large retreat occupied by several larvæ. No evidence was found of the larvæ swimming from one leaf to another as was observed by Welch in Lake Erie. The leaves were in almost every case contiguous to each other, especially when swayed by the breeze, and no need for such a means of locomotion was apparent. Then, too, the old floating leaves, loose from their petioles, drifted back and forth across the pond before the wind and, working in among the standing leaves, formed pontoon bridges between the petioles. (Pl. I, A.)

One exceptional instance was observed in which a leaf standing somewhat by itself but not especially isolated was found with a series of six holes in the petiole between the blade and water, each of which opened into a short cavity containing a fully mature larva evidently preparing to pupate. Not another larva was found in such a location, and this case can only be explained on the ground

that the larvæ marooned on this leaf, unable to seek their usual pupation quarters, were forced to enter the petiole.

From laboratory experiments it was found that when placed in water the larvæ, especially those nearly mature, were sustained on the surface film and were able to make considerable progress by lateral contortions. When once fully submerged, however, they were unable to regain the surface. Larvæ of *Pyrausta ainsliei* under the same conditions behaved similarly but did not advance as rapidly when swimming.

FEEDING HABITS ON THE PODS.

The larvæ of the first generation apparently utilize the green, growing pod for food as well as for pupation. After the floral parts fall away, the pod normally droops (Pl. I, B, *b*) until its flat, seed-bearing face is vertical, becoming erect again when nearly mature (Pl. I, B, *c*). Until maturity the seeds remain tightly embedded in their sockets, and only as the pods ripen, turn brown, and dry do they become loose, ultimately to be shaken out and sink in the water and mud around the plants.

In entering the young pod the larva usually selects a point just below the rim and on the underside of the pod as it hangs horizontally (Pl. II, A); less often it cuts in between the seeds on the flat face of the pod (Pl. II, C). As the larva feeds within, soft brown frass is pushed out of the entrance hole in considerable quantity, eventually drying and falling away or being washed off by rain. The interior of the fruit or pod is filled with parenchymatous tissue through which run the vascular bundles nourishing the developing seeds. After entering, the larva eats out more or less of a cavity in this soft tissue and often cuts into or through two or three or more of the seeds. Whenever a seed is injured even slightly or the vascular bundle beneath it is cut, it turns brown and soon shrivels to a mere remnant. These empty or partially empty sockets (Pl. II, B) are very conspicuous and almost invariably indicate the presence or work of the larvæ. Such injured pods are also frequently much distorted (Pl. I, B, *d*) and very unlike the ornamental, perfect specimens. Although in a few cases the cocoon was found near the face of the pod and, in fact, lying partially in and through some of the injured seeds, the larva usually makes its way well toward the base of the pod before cocooning.

In the pods collected at Kimberlin Heights July 19 the normal number of seeds per pod varied from 10 to 25, with an average of 17. The work of the larvæ resulted in the destruction of 5.9 seeds on the average in each infested pod, or 34.7 per cent of the total number in the infested pods and 5.88 per cent of those in the entire plantation. The pods developing from the scattering flowers which

continue to appear after the main blooming season are generally smaller, contain relatively few seeds, and often have empty sockets due to incomplete fertilization.

So far as is known, this lotus has at present no economic value other than its very obvious qualifications as an ornamental plant. The work of the larvæ of this insect on the leaves (Pl. III) is conspicuous and unsightly, and the attacks on the pods result in many misshapen and distorted specimens as well as in the outright destruction of an appreciable proportion of the seeds.

PUPATION OF THE FIRST GENERATION.

Pupæ of the first generation are formed in dense, tough, papery cocoons in the growing pods. The cocoon is not conspicuous even when the pod is opened, as it is stained and studded with brownish excrement like the walls of the burrow. In the great majority of cases it lies well toward the base of the pod with its long axis parallel with the vascular bundles running to the seed sockets. Less often it is found lying partially within or through one or more of the partly consumed seeds. The cocoon and pupa are so much larger than the seeds that it seems impossible for the pest ever to be accidentally distributed in them. Larvæ have been found lying entirely within a single immature seed but never a pupa. In the cocoon the pupa lies with its head toward the entrance, and after emergence occurs the pupal shell remains entirely within the cocoon. The moth escapes from the pod by the same opening through which the larva entered it.

PUPATION OF THE SECOND GENERATION.

In the second generation the pupal habits are quite different, and considerable search was required to locate the cocoon and pupa. Even though a few pods continued to develop from stray flowers, they were found attacked by larvæ in only one or two cases, and the increasing number of larvæ reaching maturity made it certain that they were seeking other quarters. Two possibilities were open—the over-curled margins of the leaves and the petioles. The leaf margins yielded only a very occasional pupa, not enough to solve the problem, and the petioles, standing as they did from 15 to 30 inches above the water and offering apparently ideal conditions for a pupal burrow, remained unscarred. To be sure, an occasional shallow pit was found in the upper end, opening to the upper surface of the leaf blade, but never one large enough to contain a larva.

The lotus at least in this plantation holds the leaves high above the water on their stiff and milky-juiced supporting petioles until, either from maturity or because of serious injury to the leaf surface, they have about reached their limit of usefulness. The petioles then

weaken and allow the leaf disks to drop to the surface of the water (Pl. I, A), where they soon yellow, decay, and sink. When these mature floating leaves were examined it was found that in the center of the disk, directly above the petiole attachment, a large number of the leaves had a round opening leading to a cavity in the upper end of the petiole (Pl. IV, B, C). This cavity was shallow, seldom extending more than 2 centimeters into the petiole, and usually just long enough to accommodate the larva and its cocoon. The entrance was often surrounded and covered by a mound of soft brown frass pellets (Pl. III, C), and frequently the surface tissue of the leaf in an irregular area about it was scarred and eaten as if the larva after constructing the cavity possessed still an appetite which it satisfied with the nearest food at hand.

In the case of the prepupal larvæ or pupæ the cavity in the petiole is lined with a substantial white silk fabric, densest at the upper end (Pl. IV, B). The entrance is closed with a very accurately cut whitish lenticular disk of plant tissue which fits closely and is sealed in with silk. This disk lies usually a little below the level of the leaf surface and is concealed by the frass until the latter is washed away or otherwise removed. This position of the pupal cavity, in the floating leaves only, brings it below the water level.

Welch (*14, p. 219–221*) has well described the construction of this pupal chamber and the feeding in connection therewith, and the behavior of the insects was found here to correspond closely with his account. It is noteworthy, however, that in Lake Erie, where his observations were made, the lotus leaves are always floating and not held above the water, and their centers are higher than the periphery, while at Kimberlin Heights the leaves are held 15 to 30 inches above the water and are cupped with the margins higher than the centers, so that they often catch rain or dew to the amount of several cubic centimeters and hold it until it evaporates or is spilled by the swaying of the leaves in the wind. The insect evidently prefers to construct its cocoon in an aquatic situation and so seeks the old floating leaves at the approach of maturity. Never were young or partly grown larvæ found in the petioles, only those nearly mature and probably in the last instar. Neither are the young and erect leaves attacked in this way; only the old, floating ones.

HABITS OF THE MOTHS.

The only moths seen in the open were the few found in and near the lotus plantation. Several of them were captured and found to be predominantly males. Their flight was rapid and erratic, and they were wary and not easily approached. They came to rest usually on the lower side of a lotus leaf and often flew among the petioles and beneath the canopy formed by the leaves 2 or 3 feet

above the water. No data are available as to the length of life of the moths in the open. A series of reared moths retained alive in tin boxes supplied with a wad of wet cotton furnished the data on this point contained in Table I.

TABLE I.—*Length of life of reared moths in confinement (in terms of days).*

Sex.	Maximum.	Minimum.	Average.	Number of moths averaged.
Male	14	2	6.77	27
Female	13	3	7.72	43

THE EGG.

The act of oviposition has not been observed, but very probably occurs toward dusk or at night. Nothing was known about the egg until Welch (*14, p. 214*) observed and rather incompletely described it. The authors have found numbers of the masses (Pl. II, D) at various times, and as their observations differ in some points from those of Welch a description in somewhat greater detail is included.

The eggs: Thin, flat, elliptical in outline, 0.98 millimeter long, 0.56 millimeter wide, chorion finely reticulated with narrow elevated lines and in addition finely longitudinally wrinkled, dingy yellow or amber color when laid, soon developing a narrow darker border and a paler opaque central area. They are laid in thick circular masses of 40 to 80 eggs, 2.5 to 3 millimeters in diameter and 0.47 millimeter thick, each egg overlapping its predecessor shingle-fashion, about three-fourths covering it and lying at an angle of approximately 45° with the leaf surface, the mass being dingy yellow in general color. The larva leaves the egg through a transverse slit in the exposed end. After hatching the mass is dirty gray in color, somewhat shining, and much flatter than before. It is then very loosely attached to the leaf and easily removed by a slight touch.

The writers failed to note any matrix such as Welch describes. They did, however, note the frequent absence of the empty egg mass on leaves bearing very small larvæ, but attributed the fact to the ease with which the empty egg mass is washed or blown from the leaf. A number of the egg masses were found, both unhatched and empty, and one in which the eggs were parasitized. They seem to be placed at any point on the upper surface of the leaf and when present on an unblemished leaf are easily seen.

It has, of course, been impossible to determine how many eggs are normally laid by a female in the open. The possibilities are indicated, however, by results obtained from reared moths confined in tin boxes and supplied with moisture. Of 43 females so confined only 15 oviposited. The number of eggs produced by an individual varied from 9 to 504, with an average for the 15 of 143 eggs. These moths

were all isolated before emergence and remained virgins throughout their lives, so these figures are doubtless below the normal.

FOOD PLANTS.

Unless some food plant other than lotus is inhabited by this insect, it is difficult to explain its presence at Kimberlin Heights. From present knowledge of its habits it is inconceivable that it came with the seeds, and no other lotus is known to exist within possible range of flight of this moth. To determine whether the species is indigenous or introduced, the writers have made plantings of lotus seed in several isolated ponds many miles distant from this infestation.

Because of the confusion in the literature between this species and *Pyrausta ainsliei*, several food plants have been attributed to it which manifestly are erroneous. The only natural food plants which have so far been reliably ascertained are the yellow lotus. *Nelumbo lutea*, and the Indian lotus, *N. nucifera*, the latter an introduced species.

Smith (*10, p. 525*), mentions having found these larvæ in stems of cat-tail flag, *Typha latifolia*. At Kimberlin Heights conditions were ideal for such a transfer, because the lotus and cat-tail grew intermingled in several places (Pl. IV, A). In attempts to find where the larvæ went for the winter, practically every cat-tail plant in the vicinity of the pond was thoroughly dissected and examined. With the single exception of one larva found behind a leaf sheaf no trace of attacks on this plant were found.

In confinement in the laboratory partly grown larvæ, taken on lotus, fed readily and completed their growth on leaves of smartweed (*Polygonum pennsylvanicum*), buckwheat (*Fagopyrum fagopyrum*), and dock (*Rumex crispus*). In other series, larvæ were reared from egg to adult on the same plants but the authors have never seen any indication that these plants are used as food by this insect under natural conditions. Numerous aquatic and subaquatic plants and a large number of the common wild plants and weeds were offered to the larvæ, but all were refused except those mentioned. It is noteworthy that the normal food plants of *P. ainsliei* are Polygonaceae but that that species can not develop on lotus. There is a suggestion here of some common ancestry for the two species, with members of the Polygonaceæ as their food plants, and that *P. penitalis*, having taken to lotus comparatively recently, has not entirely lost its taste for the smartweed family.

ENEMIES.

In the course of its life several perils threaten the safety of this insect. It does not seem to us that Welch's point (*14, p. 218*), as to the construction of the silken web being a special adaptation to its

aquatic environment, is well taken, for many leaf and tree-feeding caterpillars, exposed to the same or to greater risks, do not construct protective webs and, on the other hand, many larvæ living in sheltered and well-protected situations do build burrows or webs—within which to work. Be that as it may, there is probably little danger of wind or waves washing these caterpillars off the leaves.

DIPTEROUS PARASITES.

From living enemies, however, they do not escape so easily. According to the literature four species of tachinid flies have been reared from the larvæ. Townsend (*5*) lists *Exorista hirsuta*. O. S. (now *E. vulgaris* Fall.) and *Phorocera comstockii* Will. as having been reared by Forbes in Illinois. Coquillett (*7*, *p. 17*, *19*) adds *Hypostena variabilis* Coq. and *Panzeria penitalis* Coq. to this list. Because of the confusion between *Pyrausta penitalis* and *Pyrausta ainsliei* and the impossibility of finding from the literature the exact source of the material from which the parasites were reared, it is possible that not all of these species attack the true *Pyrausta penitalis*. *Panzeria penitalis*, for one, is known to be a parasite of *Pyrausta ainsliei*, and there is no definite record of its ever having been reared from lotus-feeding larvæ. All of these records should be verified in the light of our more exact knowledge of their hosts.

HYMENOPTEROUS PARASITES.

Among the hymenopterous parasites, *Bracon xanthostigma* Cress. is listed by Riley and Howard (*4*, *p. 439*) as a parasite of this borer on lotus at St. Louis, Mo. Viereck (*11*, *p. 223*) lists *Meteorus communis* Cress. with the simple statement that it parasitized *P. penitalis*. Hart (*6*, *p. 180*) mentions one secondary and two primary parasites, but without determinations. We recognize at least one of his parasites, the braconid, making white cocoons singly on the leaf surface. (Pl. III A.) This one, determined as *Apanteles harti* Vier. by A. B. Gahan, was found to be the most common at Kimberlin Heights. Its small white cocoons (1.5 by 4 millimeters) are firmly fastened to the leaf disk either under the webbing or exposed outside. In July they were only occasionally seen, but by early September were much more common and were killing from 10 to 25 per cent of the larvæ. This species evidently attacks the smaller larvæ and completes its life as a parasite when its host is scarcely more than half grown. None of them developed from larvæ larger than this. From 7 to 10 days elapsed between the spinning of the cocoon by the parasite and the emergence of the adult.

Another parasite, very likely the other mentioned by Hart (*6*, *p. 181*), which the writers found only a little less common than the foregoing, is an undescribed, yellowish brown species of Microbracon (de-

termined by Gahan). The parasitic grubs to the number of about a dozen emerge from their host larva shortly before time for the pupation of the latter. They then spin a mass of brown silk cocoons so tightly compacted that it is difficult even to determine their number. This mass is found in the burrow or partially constructed cocoon of the host. In more than one instance adults of this parasite were found well within the larval burrow of the host, evidently hunting opportunities for oviposition, but it is not known just how or at what age the host larvæ are attacked.

In three instances *Chalcis ovata* Say (det. Rohwer) was reared from the pupæ by the authors.

The authors found but one case of egg parasitism. One egg mass was taken which appeared darker than normal. When retained in a vial, part of the eggs hatched normally, but the rest, which had meanwhile turned jet black, gave forth adults of *Trichogramma minutum* Riley (det. Gahan), one from each egg.

SCAVENGERS.

Very often small dipterous maggots were found in the empty burrows or feeding on decaying larvæ or pupæ. A number were reared, and two species of flies were obtained, *Aphiochaeta chaetoneura* Malloch (det. Greene), and *Elachiptera nigriceps* Loew (det. Aldrich). These were undoubtedly scavengers, and nothing was observed to indicate that they were in any way injurious to sound larvæ or pupæ. They seem to thrive equally well on putrid vegetable matter. Coquillett (*8*) mentions rearing the latter of the two species from the same situation many years earlier.

OTHER ENEMIES.

A somewhat peculiar catastrophe was found to happen very often to the larvæ which had prepared their pupation chambers in the upper end of the petioles of the floating leaves. Some animal, evidently, took a bite out of the side of the petiole close under the leaf, thereby cutting into the cavity and its occupant. In some such cases the cut-out portion of the petiole was left hanging, in others it was gone, and often the predator had bitten the petiole entirely off at this point. No portion of the larvæ or pupæ was ever found in the cavity, and the work was very evidently done intentionally in search for the insect. Often uninfested petioles were cut, evidently by mistake. The possible authors of the work were (1) ducks, a small flock of which frequented the pond; (2) frogs, of which there were many, some of them very large; (3) fishes; and (4) turtles. The character of the work eliminates the ducks and frogs because their jaws are not sufficiently strong to make such clean cuts as these were. No direct evidence of the presence of fish was found, and in such

a pond it would not be usual to find fish capable of doing such work. There remain the turtles, whose heads were frequently seen above the water. The authors were unable to capture any to examine their stomach contents, but by elimination they appear to be the most probable authors of the mischief. Doctor Welch writes that he observed nothing of the kind in Lake Erie. The effect of the work of this depredator was a substantial reduction in the number of larvæ reaching maturity.

LITERATURE CITED.

(1) Grote, A. R.
1876. new pyralids. *In* Canad. Ent., v. 8, no. 5, p. 98–99.

(2) Coquillett, D. W.
1880. on the early stages of some moths. *In* Canad. Ent., v. 12, no. 3, p. 43–46.

(3) Smith, John B.
1890. a new species of botis. *In* Entomologica Americana, v. 6, no. 5, p. 88–90, 2 figs.

(4) [Riley, C. V., and Howard, L. O.]
1890. some of the bred parasitic hymenoptera in the national collection. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 2, no. 11/12, p. 348–353.

(5) Townsend, C. H. Tyler.
1893. hosts of north american tachinidæ. *In* Psyche, v. 6, no. 206, p. 466–476.

(6) Hart, C. A.
1895. on the entomology of the illinois river and adjacent waters. *In* Bul. Ill. State Lab. Nat. Hist., v. 4, art. 6, p. 149–273, pl. 1–15.

(7) Coquillett, D. W.
1897. revision of the tachinidæ of america north of mexico. U. S. Dept. Agr. Div. Ent. Tech. Ser. no. 7, 165 p.

(8) ———.
1898. on the habits of the oscinidæ and agromyzidæ reared at the united states department of agriculture. *In* U. S. Dept. Agr. Div. Ent. Bul. 10 (n. s.), p. 70–79.

(9) Dyar, Harrison G.
1902. a list of north american lepidopetra and key to the literature of this order of insects. U. S. Nat. Mus. Bul. 52, xix+723 p. List of works quoted, p. ix–xix.

(10) Smith, John B.
1910. the insects of new jersey. *In* Ann. Rpt. N. J. State Mus., 1909, p. 14–880, 340 fig. (partly on pl.).

(11) Viereck, Henry Lorenz, et al.
1916. guide to the insects of connecticut. pt. iii. the hymenoptera, or wasplike insects, of connecticut. Conn. State Geol. and Nat. Hist. Survey Bul. 22. 824 p., 10 pl.

(12) Chittenden, F. H.
1918. the lotus borer. *In* Jour. Econ. Ent., v. 11, no. 6, p. 453–457, pl. 16.

(13) Mosher, Edna.
1919. notes on lepidopterous borers found in plants, with special reference to the european corn borer. *In* Jour. Econ. Ent., v. 12, no. 3, p. 258–268, fig. 11–14.

(14) WELCH, PAUL S.
1919. THE AQUATIC ADAPTATIONS OF PYRAUSTA PENITALIS GRT. (LEPIDOPTERA). *In* Ann. Ent. Soc. America, v. 12, no. 3, p. 213–226. Literature cited, p. 226.

(15) MOSHER, EDNA.
1919. NOTES ON THE PUPÆ OF THE EUROPEAN CORN BORER, PYRAUSTA NUBILALIS, AND THE CLOSELY RELATED SPECIES P. PENITALIS. *In* Jour. Econ. Ent., v. 12, no. 5, p. 387–389, fig. 18–19.

(16) HEINRICH, CARL.
1919. NOTE ON THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HÜBNER) AND ITS NEAREST AMERICAN ALLIES, WITH DESCRIPTION OF LARVÆ, PUPÆ, AND ONE NEW SPECIES. *In* Jour. Agr. Research, v. 18, no. 3, p. 171–178, pl. 7–11.

(17) FLINT, WESLEY P., and MALLOCH, JOHN R.
1920. THE EUROPEAN CORN BORER AND SOME SIMILAR NATIVE INSECTS. *In* Ill. Div. Nat. Hist. Survey, Ent. Ser., v. 13, art. 10, p. 287–305, 44 fig.

(18) AINSLIE, GEORGE G., and CARTRIGHT, W. B.
1921. BIOLOGY OF THE SMARTWEED BORER, PYRAUSTA AINSLIEI HEINRICH. *In* Jour. Agr. Research, v. 20, no. 11, p. 837–844. Literature cited, p. 844.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽